3D Science Performance Assessment Tasks

HIGH SCHOOL

CHEMICAL REACTIONS

In Partnership with

3DSPA Assessment Tasks were developed by

CMU Central Michigan University | Central Michigan SMTC Science Mathematics Technology Center

A member of Michigan Math & Science Centers Network

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Task Title	Where did the CO_2 Go?

Standards Bundle
PEs • HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. • HS-PS1-6 PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* • HS-PS-1-7 PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. * The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.
Practices • Planning and Carrying Out an Investigation • Constructing Explanations and Designing Solutions • Using Mathematics and Computational Thinking
Cross-Cutting Concepts • Energy and Matter - The total amount of energy and matter is conserved. • Stability and Change - Much of science deals with constructing explanations of how things change and how things remain stable. • Patterns - Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality and evidence for phenomena.
Core Ideas • PS1.B Chemical Reactions - In many situations, a condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. • PS1.B Chemical Reactions - Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of collisions of molecules and the rearrangement of atoms into new molecules with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. • PS1.B Chemical Reactions - The fact that atoms are conserved, together with the knowledge of chemical properties of the elements involved, can be used to describe and predict chemical reactions. • ETS1.C Optimizing the Design Solution - Criteria may need to be broken down into simpler that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
CCSS ELA: • RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5) • WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-5) • WHST 9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6)
CCSS Mathematics:

- MP.2 Reason abstractly and quantitatively. (HS-PS1-7)
- HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-7)
- HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-7)
- HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-7)

Overview / Introduction of the Assessment Task

In this task, students will spend several days working to determine the correct concentration of vinegar to use to produce the expected moles of oxygen from a vinegar baking soda experiment.

Teacher Background
Teacher background information: Chemical Equilibrium – Real Life changes Lab Reaction Rates
Information for Classroom Use
Connections to Instruction: This task is designed to be a culminating project at the end of the unit about balancing chemical reactions.
Approximate Duration for the Summative Task: (all components) The task will take approximately four days.
Assumptions: It is assumed that students know how to calculate moles of product produced, how concentration of reactants affect reaction rate, how to balance a chemical reaction and how to convert grams to moles.
Materials Needed: vinegar, sodium bicarbonate, 100 ml beaker, flask, balloons, scales, funnel, weighing boat
Supplementary Resources: Next Gen Standards Information Link 1 Link 2

Performance Assessments

Learning Performances
Evidence: 1. Students identify and describe evidence to construct the explanation, including: a. Evidence (e.g. from a table of data) of a pattern that increases in concentration (e.g., a change in one concentration while the other concentration is held constant) increases the reaction rate, and vice versa b. Evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa. Reasoning: 1. Students use and describe the following chain of reasoning that integrates evidence, facts and scientific principles to construct the explanation: a. Molecules that collide can break bonds and form new bonds, and produce new molecules. b. The probability of bonds breaking in the collision depends on the kinetic energy of the collision being sufficient to break the bond, since bond breaking requires energy. c. Since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds. d. At a fixed concentration, molecules that are moving faster collie more frequently, so molecules with higher kinetic energy are likely to collide more often. e. A high concentration means that there are more molecules in a given volume and thus more particle collisions per unit of time at the same temperature. Using scientific knowledge to generate the design solution 1. Students identify and describe potential changes in a component of the given chemical reaction system that will increase the amounts of particular species at equilibrium. Students use evidence to describe the relative quantities of a product before and after changes to a given chemical reaction system (e.g., concentration increases, decreases or stays the same), and will explicitly use Le Chatelier’ s principle, including: a. How, at a molecular level, a stress involving a change to one component of an equilibrium system affects other components; b. That changing the concentration of one of the components of the equilibrium system will change the rate of the reaction (forward or backward) in which it is a reactant, until the forward and backward rates are again equal; and c. A description of a system at equilibrium that includes the idea that both the forward and backward reactions are occurring at the same rate, resulting in a system that appears stable at the macroscopic level. d. Describing criteria and constraints, including quantification when appropriate e. Students describe the prioritized criteria and constraints, and quantify each when appropriate. f. Examples of constraints to be considered are cost, energy required to produce a product, hazardous nature and chemical properties of reactants and products, and availability of resources. 2. Evaluating potential solutions a. Students systematically evaluate the proposed refinements to the design of the given chemical system. b. The potential refinements are evaluated by comparing the redesign to the list of criteria (i.e., increased product) and constraints (e.g., energy required, availability of resources). 3. Refining and/or optimizing the design solution a. Students refine the given design system by making tradeoffs that would optimize the designed system to increase the amount of product, and describe the reasoning behind design decisions.

4. Students identify and describe the relevant components in the mathematical representations:
    a. Quantities of reactants and products of a chemical reaction in terms of a atoms, moles, and mass;
    b. Molar mass of all components of the reaction;
    c. Use of balanced chemical equations; and
    d. Identification of the claim that atoms, and therefore mass, are conserved during a chemical reaction.

5. The mathematical representations may include numerical calculations, graphs or other pictorial depictions of quantitative information.
    a. Students identify the claim to be supported that atoms, and therefore mass are conserved during a chemical reaction.

6. Mathematical modeling
    a. Students use the mole to convert between the atomic and macroscopic scale in the analysis.
    b. Given a chemical reaction, students use the mathematical representations to
    c. Predict the relative number of atoms in the reactants versus the products at the atomic molecular scale; and calculate the mass of any component of a reaction, given any other component.

7. Analysis
    a. Students describe how the mathematical representations (e.g., stoichiometric calculations to show that the number of atoms or number of moles is unchanged after a chemical reaction where a specific mass of reactant is converted to product) support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
    b. Students describe how the mass of a substance can be used to determine the number of atoms, molecules, or ions using moles and mole relationships (e.g., macroscopic to atomic molecular scale conversion using the number of moles and Avogadro's number).

Phenomenon and Driving Question	Expected Student Outcome / Scenario
An unbalanced baking soda and vinegar reaction Does the Conservation of Mass Apply to this Chemical reaction?	On Day 1, students will find that the Law of Conservation of Mass is not true for the experiment. This is because the concentration of vinegar is not strong enough to convert the baking soda to create the appropriate amount of CO_2. However, students will be unaware of this at this stage. On day 2 and 3 students will have to work backwards to calculate how much vinegar to use to produce the desired amount of CO_2 by designing and implementation of an experiment to determine the optimum concentration of vinegar to produce the desired amount of CO_2. The final product will be a poster that represents the process and analyzes the data they collect.

Student Performances		
Formative Assessment Task 1	Learning Performance: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium	Expected Duration: 1 day
	Description (Phenomena, Scenario, Task): Students will be able to describe changes in equilibrium of chemical reactions as concentration increases or decreases. Khan Academy Youtube Video Bozeman Science Video	
	Directions: Give students situations in which the concentration of reactants changes and thus a new equilibrium is formed.	
	Scoring / Teacher Look-For's: Teachers need to determine if students understand that as concentration of reactants change, then the concentrations of products will also change and a new equilibrium will be formed.	
Formative Assessment Task 2	Learning Performance: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	Expected Duration: 1 day
	Description: Dissolving of sugar in water: Students will be able to describe how temperature, concentration, stirring, surface area and catalysts will change the rates of reactions and be able to relate this to the collision of atoms and molecules.	
	Directions: Students will conduct an experiment in which they will determine the effect of surface area and temperature on how quickly sugar cubes dissolve in water. Rates of Chemical Reactions	
	Scoring / Teacher Look-For's: Teachers need to determine that students can describe how changes in temperature, concentration of reactants, stirring, and surface area of reactants affect chemical reaction rates and are able to relate this to the frequency of collisions of atoms/molecules.	
Formative Assessment Task 3	Learning Performance: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	Expected Duration: 1 day
	Description (Phenomena, Scenario, Task) Students will be able to convert between moles, mass and atoms.	
	Directions Provide students with problems in which they will determine the numbers of grams, moles or atoms produced. Possible activity: Moles Conversion Moles Again Conversion	
	Scoring / Teacher Look-For's: Teachers should determine that students are able to convert between atoms, moles and mass.	

<table>
<tr><td rowspan="4">Formative Assessment Task 4</td><td colspan="2">Learning Performance:
Use a mathematical representation to identify and describe the quantities of reactants and products in a reaction in terms of atoms, moles and mass.</td><td rowspan="4">Expected Duration:
1 day</td></tr>
<tr><td colspan="2">Description (Phenomena, Scenario, Task) Students will complete the day one activities for the experiment “Where did the CO_2 go?”</td></tr>
<tr><td colspan="2">Directions Students will determine the amount of CO2 produced during the reaction by completing the activity without collecting the gas produced and then repeating the activity and collecting the gas. The difference is the amount of CO2 produced.
Student directions
Where did the CO2 Go? Day 1</td></tr>
<tr><td colspan="2">Scoring / Teacher Look-For’s: At the completion of the activity be sure to have students look at the flask. There should be left over baking soda that was never used during the reaction. This will set up day 2 and 3. Students should notice that they do not produce the amount of CO_2 expected.</td></tr>
<tr><td rowspan="4">Final Task:
(Model, Design, Explain, Argue, Investigate)</td><td colspan="2">Phenomena:
When sodium bicarbonate and vinegar react, carbon dioxide is produced and the reaction does follow the law of conservation of mass.
$C_2H_4O_2 + NaHCO_3 \rightarrow NaC_2H_3O_2 + H_2O + CO_2$</td><td rowspan="4">Expected Duration:
2 to 3 days

2 to 3 days
1 for experiment:
2 for production of presentation</td></tr>
<tr><td>Goal:
The Insta Cold Dry Ice company is investigating new sources of CO_2 for their business. You and your team will need to determine the exact ratios of reactants to produce the desired yield while being conscious of waste product production.</td><td>Role:
Lead chemist on a team asked to investigate the question</td></tr>
<tr><td>Audience:
The CEO or the Inst Cold Dry Ice company who is looking for a new source of CO_2.</td><td>Situation:
The vinegar concentration is too weak to produce the equivalent amount of CO_2 as expected so students will be tasked to determine what concentration of the vinegar will be needed to produce the desired moles of CO_2.</td></tr>
<tr><td colspan="2">Product / Performance:
Produce a poster that demonstrates your learning and understanding of your day 2 and 3 activity. Your poster will be presented to the CEO of the Insta Cold Dry Ice Company to help her determine a new source of CO_2. It should include:
● Detailed explanation of the experiments completed in the process to determine the required reactants.
● Analysis of data from experiments
● Account for matter (atoms/mass before and after reaction using moles)
● Explanation of application of the Le Chatelier Principle.
Analysis of the priority of criteria (trade-offs) needed to determine the optimum concentrations vs waste product to produce the optimum CO_2 level.</td></tr>
</table>

	Directions: During the Day 1 experiments, you did not produce the expected amount of Carbon dioxide. One of the reactants is a limiting factor to the reaction. With your group your task is to design an experiment to determine the correct concentration of reactants to produce the amount of Carbon dioxide you expected and to determine which reactant was the limiting factor. Be sure to take copious notes to ensure that your experiment may be replicated, and you have plenty of data for your report you will need to make to the company CEO. **Things to consider:** ● Remember what your beaker looked like at the end of the experiment yesterday. Can you determine which reactant was not completely consumed by the reaction? ● Calculate the number of moles of this reactant. ● Using the balanced chemical reaction, determine the number of moles of CO_2 should be produced. Convert this to grams. You now know the amount of CO_2 you be able to produce from this reaction. ● Use this information to determine the amount of the other reactant to use to produce this amount of CO2. ● Consider the amount of waste produced vs optimum concentrations of reactants. Teacher Directions Student Directions: Where is did the CO2 go? Day 2 and 3	

CheckBric

Student Name ____

Teacher Name ____

Learning Performance: Students will be able to analyze data from experiments to account for all matter before and after reaction to show that mass is conserved.					**Comments**
Insert Evidence Statements below:					
Graphical display of data from the experiments. ● create data chart that includes all trials ● Identifies changes made to concentrations	**1**	**2**	**3**	**4**	
Account for matter (atoms/mass/moles before and after reaction) ● Explanation of number of moles of vinegar ● Explanation of calculations of how many moles of CO_2 will be produced. ● Conversion of moles of CO_2 to grams	**1**	**2**	**3**	**4**	
Analysis of claim that atoms, and therefore mass, are conserved during a chemical reaction. ● Discussion of why you can determine the number of moles of product formed if the number of moles of reactants is know.	**1**	**2**	**3**	**4**	
LP Total:					
Learning Performance: Students will be able to refine and redesign the experiment to determine the optimum amount of reactants to produce the desired amount of products.					**Comments**
Insert Evidence Statements here:					
Describe procedure used. ● Detailed reproducible procedure identified. ● Includes changes made by redesign	**1**	**2**	**3**	**4**	
Refine the given design that would optimize the designed system to increase the amount of product, and describe the reasoning behind design decisions. ● Describe each redesign ● Describe reasoning for redesign	**1**	**2**	**3**	**4**	
Analysis of the priority of criteria (trade-offs) needed to determine the optimum concentrations vs waste product to produce the optimum CO_2 level. ● Analysis of procedure to create optimum concentration of CO_2. ● Discussion of optimum concentration vs amount of waste product	**1**	**2**	**3**	**4**	

Consider limitations of the precision of the data (e.g., number of trials, cost, risk, time) ● Identification of limitations (limitation of balance, cost, number of trials)	**1**	**2**	**3**	**4**	
LP Total:					
Learning Performance: Students will be able to apply Le Chatelier's principle and use evidence to provide an explanation about the effects of changing the concentration of the reacting particles on the production of products.					**Comments**
Insert Evidence Statements here:					
Explanation of application of the Le Chatelier's Principle. ● State Le Chatelier's Principle ● Explanation of principle as it applies to experiment and redesign.	**1**	**2**	**3**	**4**	
Students describe multiple changes made to experiment that change the reactants. ● Identify at least three changes made to the design during subsequent redesigns.	**1**	**2**	**3**	**4**	
Evaluate the resulting changes to the amount of CO_2 produced caused by changes in concentration. ● For each change in concentration, evaluate how it changed the amount of CO_2 produced.	**1**	**2**	**3**	**4**	
LP Total:					
Checkbric Total					

4 Exemplary	Work at this level is of exceptional quality. It is both thorough and accurate. It exceeds the standard. It shows a sophisticated application of knowledge and skills.
3 Proficient	Work at this level meets the standard. It is acceptable work that demonstrates application of essential knowledge and skills. Minor errors or omissions do not detract from the overall quality.
2 Developing	Work at this level does not meet the standard. It shows basic, but inconsistent application of knowledge and skills. Minor errors or omissions detract from the overall quality. Your work needs further development.
1 Emerging	Work at this level shows a partial application of knowledge and skills. It is superficial (lacks depth), fragmented or incomplete and needs considerable development. Your work contains errors or omissions.